

**Stability Theory.** Hurwitz Centenary Conference, Centro Stefano Franscini, Ascona. 1995. R. Jeltsch and M. Mansour eds. Birkhäuser Verlag. 1996. Price: Fr 128, Dm 148.

Stability theory is one of those classical areas of study which appear in new garbs from time to time. It originally arose in connection with the study of mechanics, particularly connected with heavenly bodies. In more recent times stability theory has formed the backbone of the study of control systems. After all, one must guarantee that a system is stable, before one can expect other properties such as accuracy, noise rejection and optimality.

In the eyes of a control theorist, the simplest dynamic system is described by a linear differential equation with constant coefficients. Such systems are called linear time-invariant systems. It is not so well known that J. C Maxwell, whose fame from electromagnetic theory overshadowed everything else that he did, was also the originator of stability studies of such systems. Studying Watts' governors for steam engines, he was led to conclude that stability of linear time-invariant systems essentially reduces to the location of the roots of an algebraic equation in the open left half plane. Although Maxwell was able to obtain stability conditions on the coefficients for only third order systems, he stated the problem in a clear manner and paved the way for others to try for a complete solution.

Hermite, Routh and Hurwitz obtained stability criteria for general  $n$ th order systems. The Hurwitz criterion was published in 1895 in *Mathematische Annalen*. Although Hermite had obtained an equivalent result earlier (1854), it did not attract much attention till recent times possibly because of the form in which it was stated. Routh's criterion (1877) was well known in England, but surprisingly Hurwitz was unaware of it, perhaps due to the weak channels of communication between researchers at that time. The present volume is essentially a collection of papers presented at the Hurwitz centenary conference held at Ascona, Switzerland in May 1995.

Adolf Hurwitz was a Professor at ETH in Zurich, Switzerland. The present volume is edited by Rolf Jeltsch and Mohamed Mansour, both faculty members of ETH. Thus the volume is a tribute paid to a former member of ETH by the present

faculty members of the same Institution. The main part of the book is divided into three sections as follows: (i) Stability Theory, (ii) Robust stability, and (iii) Numerics. A list of 11 open problems follows the 3 sections and the book concludes with the original paper by Hurwitz in German.

A Hurwitz matrix is a matrix obtained from the coefficients of the polynomial derived from the linear differential equation which is being investigated for stability. According to the Hurwitz criterion, the positiveness of the leading principal minors of this matrix is necessary and sufficient for the zeros of the polynomial to be confined to the open left half of the complex plane. While this solves the stability problem, many researchers have gone further and extracted other useful information from the Hurwitz matrix. The paper by Beghi *et al.* tells us how the so-called second order information indices of a transfer function (i.e. energies associated with a related impulse response and its derivatives) can be obtained from the Hurwitz matrix and uses them to find reduced-order models which retain the same information indices.

The well-known Orlando formula is a landmark in establishing a useful relation between the Hurwitz determinants and the polynomial whose roots are the sums of the roots of the given Hurwitz polynomial. The paper by Gorecki *et al.* generalizes this result to polynomials whose roots are linear combinations (with fixed integer coefficients) of the given Hurwitz polynomial. This leads to a new method for calculation of a generalized integral criterion.

There are some papers dealing with basic theoretical issues connected with the Hurwitz criterion. Garloff and Srinivasan's contribution is based on the concept of the Hadamard product which is the coefficient-wise product of two polynomials. The authors show that the set of Hurwitz polynomials is closed under the Hadamard product, whereas, surprisingly, the property does not carry over to Schur polynomials whose eigenvalues are inside the unit circle.

Genin considers the relationship between the two equivalent approaches of the Cauchy index of a real rational function and the index theory of pseudo-lossless rational functions. This is utilized in providing a new simple proof of Kharitonov's theorem which is the basis of most of the modern work on robust

stability. (We will see more of this later in discussing robust stability.)

There are a couple of other papers which do have overlap with the section on robust stability. Bernhardsson *et al.* give a summary of the Real Stability Radius and Real Perturbation values. These give quantitative estimates of the extent of real perturbations of system elements of complex matrices needed to drive a related system to the verge of instability. The authors show connection of these concepts to other parts of mathematics such as Hermitian Symmetric Inequalities, The Moment Problem, consimilarity and Reproducing Kernel Hilbert Spaces.

The paper by Atanassova *et al.* (with Kharitonov as a coauthor) gives analytic criteria ensuring Hurwitz stability of segments of real quasipolynomials of delay type given by

$$f(z) = p_0(z)e^{\tau_0 z} + p_1(z)e^{\tau_1 z} + \dots + p_m(z)e^{\tau_m z},$$

where  $p_j(z)$ ,  $j = 0, 1, \dots, m$  are polynomials and  $\tau_0 < \tau_1 < \dots < \tau_m$  are real numbers representing 'delays'. The paper utilizes the concept of convex stability directions for such quasi polynomials.

Some papers extend the Hurwitz criterion to other domains. Kraus *et al.* obtain a generalized Hurwitz matrix for polynomial matrices which are used, for instance, in the analysis of multiple-input, multiple-output (MIMO) systems. The key idea used here is the relation between the Hurwitz matrix for a polynomial and the Lyapunov equation in the Kronecker form. Hari C. Reddy *et al.* extend the concept of Hurwitz polynomials to two-dimensions. A detailed classification and testing of various two-dimensional Hurwitz polynomials is presented in this paper. Such studies are currently very relevant in connection with two dimensional digital filters, 2-variable reactance functions and two-dimensional positive real functions.

A few papers in the section deal with the concept of stability in different contexts, not necessarily related to the Hurwitz criterion. Sontag and Sussman consider nonlinear systems and establish the equivalence between controllability and existence of certain types of Lyapunov functions, called here as control-Lyapunov functions. The proof relies on viability theory and optimal control techniques. The paper by Strietzel attempts to analyse stability of fuzzy control systems, which are by

nature highly nonlinear. Classical concepts such as describing functions are applied. An interesting idea is that of a stability supervisor which generates the needed stabilizing input to the plant, by measuring changes in the Lyapunov function.

In the sole contribution from India, Vidyasagar considers a neural network that performs discrete optimization over  $(0,1)^n$ . When the objective function is a multilinear polynomial, almost all trajectories converge to a local maximum in a finite time, and in fact it is possible to make them converge arbitrarily quickly. The results are regarded as significant in the development of a theory of complexity of analog computation.

In a lucid historical review, leading present-day stability theorist Eliahu Jury provides a comparison of the work of four illustrious mathematicians of the nineteenth century, namely Hermite, Routh, Lyapunov and Hurwitz which totally affected research on stability in the 20th century. Five important applications of the Hurwitz criterion are mentioned in the paper.

Studies on robust stability in recent times are based on a fundamental result by Kharitonov. When the coefficients of the polynomial being investigated could lie anywhere in known intervals, the surprising result obtained by Kharitonov was that stability could be established by studying the stability of 4 related polynomials having coefficients selected from the end points of the intervals. This fundamental discovery has led to many related studies on robust stability.

There are six papers in the section on robust stability. Anderson and Dasgupta give the extension of a number of passive multiplier theory-based results to time-varying and multivariable settings. The heart of these extensions is the existence of square roots of operators representing stable multivariable and/or linear time varying systems which are stable under all scalar, constant positive feedback gains.

A robust adaptive control law for possibly non-minimum phase systems is given by Lozano and Sua'ez using a standard least squares algorithm with a dead zone. The control law ensures boundedness of all the closed loop system signals and the closed loop poles can be asymptotically assigned arbitrary values.

Stability of systems described by a linear differential equation whose coefficients vary inside given intervals and with restricted magnitudes of rates of change is

considered by Mansour and Anderson. This is obviously a generalization of the Kharitonov problem to time-varying coefficients. Using Lyapunov functions, extreme point results which give sufficient conditions for stability, are obtained.

Siemel brings out the interesting fact that while the computational effort needed for robust stability analysis increases rapidly with the number of uncertain parameters, the analysis can be performed extremely fast for the so-called tree-structured systems which frequently occur in practice. Also one can generate the stability profile which is the right hand side of the boundary of the root set and hence contains the most important stability information. Wu and Mansour give a solution of the robust stability problem of polynomial families whose coefficient vectors are affine in an uncertain parameter vector bounded by the  $l_p$ -norm. The paper by Zeheb considers the concept of local convex directions for a given Hurwitz polynomial and gives a simple algorithm to find a continuum of polynomials which form such directions.

Most of the five papers in the section on Numerics deal with the stability of discretization procedures in ordinary and partial differential equations. There is a paper by Collins and another by Liska and Steinberg which use a method of symbolic computation in the form of an algorithm called Quantifier Elimination Using Partial Cylindrical Algebraic Decomposition (QEPCAD). The former paper approximates a polynomial by another of lower degree while the latter is concerned with initial value problems in partial differential equations.

The papers by Jeltsh and Trummer consider stability of numerical methods for differential equations. The former paper also relates it with other aspects such as accuracy of the methods. Sreedhar gives a fast algorithm to compute the real structured stability radius with reference to the open left half plane or the open unit disc. This is based on a well-known correspondence between the singular values of a transfer function matrix and the imaginary eigenvalues of a related Hamiltonian matrix.

The section on Open Problem lists 11 unsolved problems mostly continuing the topics explored in the papers. These are on topics such as stability of a convex set of matrix polynomials, robust stability and passivity, real perturbation values, time-varying stable interval systems, simplest

possible property of Hurwitz criterion, representation of transfer functions in continued fractions and the robust stability of controllers for fuzzy plants. The problems appear to be mostly fundamental and quite complex. They could inspire new lines of attack on problems known to be hard.

The crowning part of the book is the original paper by Hurwitz in German. This is certainly a gift by the editors as the paper is not easily available. Even a passing acquaintance with German is adequate to appreciate the author's ease of approach in the derivation of the stability criterion. An English translation would have benefited the readers immensely.

In common with other conferences of this type, it is too much to expect that all the papers would be of interest to a researcher in stability theory. However, most researchers would find at least a paper or two in their area of concern. It goes to the credit of the editors that they have been able to collect contributions on a wide range of problems in Stability Theory. I think Hurwitz would have been happy to see the many directions in which his criterion has been refined, extended and utilized for problems not necessarily confined to stability.

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**Noam Chomsky: A Life of Dissent.** Robert F. Barsky. The MIT Press, 55, Howard Street, Cambridge, Massachusetts 02142-1399, USA. 1997. Price: \$27.50. 236pp.

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This is an adulatory political biography of Noam Chomsky. The author, who is an assistant professor in the Department of English at the University of Western Ontario in Canada, gives as his reasons for writing the book: 'Chomsky is one of this century's most important figures, and has been described as one who will be for future generations what Galileo, Descartes, Newton, Mozart, or Picasso has been for ours. . . . I believe much can be learned by looking at Chomsky's life and work in the context of the milieu from which they have emerged and to which they have contributed ....' (p. 3,5).

For over 50 years Chomsky has been a prolific speaker and writer. According to the author, Chomsky has published over 70 books and over 1000 articles in a range of fields including linguistics, philosophy, politics, cognitive sciences, psychology. ... According to *Arts and Humanities Citation Index* he is eighth on a short list of the most cited figures of all time. The first ten entries in the list, in order, are: Marx, Lenin, Shakespeare, Aristotle, the *Bible*, Plato, Freud, Chomsky, Hegel, Cicero. (p. 3).

A constantly recurring theme in Chomsky's life and work is his contention that academia (i.e. intellectuals) and the State have an inevitable self-serving tendency to collude to 'manage' the lives of ordinary people. 'The reasons academics often assume this managerial role in relation to Society, Chomsky feels, are related to their quest for power ... and the high-level of indoctrination to which they have been submitted as members of a ruling elite.' The author notes that 'Chomsky's views on these matters are often similar to those of the thinkers who had a formative influence on his outlook, notably Bakunin and Pannekoek.' (p. 165).

The basic problem with this attitude is that while in some cases (perhaps, even in many cases) it may be true, to assert that it is necessarily true in all cases leads to counter-productive consequences. Chomsky seems to have a tendency to assess all situations in terms of two polarized extremes admitting no possibilities of grey shades in between. This results in an intolerant attitude, and a refusal to admit the possibility of alternative modes of action equally honest and equally well-meaning. I would like to illustrate this with a couple of examples from the book under review.

In the context of intellectuals' participation in protest movements, Chomsky says about himself: '... I knew that signing petitions, sending money, and showing up now and then at a meeting was not enough. I thought it was critically necessary to take a more active role, and I was well aware what that would mean. It is not a matter of putting a foot in the water now and then, getting it wet and then leaving. You go in deeper and deeper. And I knew that I would be following a course that would confront privilege and authority.' (p. 124).

Chomsky criticizes Einstein for what (according to Chomsky) he should have done but did not do. 'Compare Russell and Einstein, two leading figures, roughly the

same generation. They agreed on the grave dangers facing humanity, but chose different ways to respond. Einstein responded by living a very comfortable life in Princeton and in dedicating himself to research that he loved, taking a few moments for an occasional oracular statement. Russell responded by leading demonstrations and getting himself dragged off by the cops, writing extensively on the problems of the day, organizing war-crime trials, etc. The result: Russell was and is reviled and condemned. Einstein is admired as a saint. Should that surprise us? Not at all.' (pp. 32-33).

Here is a counterview from Chekov. Why Chekov? Because, he is not a person who could be easily fooled about ordinary people, for as he himself says about himself: 'There is peasant blood in my veins and you cannot astonish me with peasant virtues.' And he goes on: '... reason and justice tell me that in electricity and steam there is more love of man than in chastity and abstinence from meat. War is evil and law is evil, but it does not follow from that that I must wear wooden shoes and sleep on the oven with my labourer and his wife....' May be Einstein's 'devoting himself to research that he loved' resulted in longer-term benefits to humanity.

Chomsky's utterly negative gut-reaction to B. F. Skinner and his approach to the study of human behaviour (i.e. Behaviourism) is well-known. In an interview on this subject Chomsky said: '... As far as the Skinner thing is concerned ... I think it is a fraud, there's nothing there. I mean it is empty. It's an interesting fraud ... I mean there are no principles there that are non-trivial, that even exist .... Why is [there] so much interest in it [then]? And here I think the reason is obvious. I mean that the methodology that they are suggesting is known to every good prison-guard, or police interrogator. And they make it look benign, and scientific, and so on. They give a kind of coating to it and for that reason it is very valuable to them...' (pp. 99-100).

In one sweep of the brush, a whole generation of psychologists is tarred. It just does not occur to Chomsky that there is a possibility of someone mistakenly, misguidedly, but genuinely and honestly (without any ulterior motive whatever), believing in the scientific validity of behaviourist principles applying to human behaviour. One can see the exemplification of the same kind of paranoia and intolerance in the following case.

'... In the early 1950s, debate was raging over the breakthroughs that new technology was promising in the understanding of human behaviour. Computers, electronics, acoustics, mathematical theory of communication, and Cybernetics were all in vogue, and researchers were busy exploiting them. Chomsky, a graduate student in his early twenties, was uneasy with this activity: 'some people, myself included, were rather concerned about these developments, in part for political reasons, at least as far as my own motivation was concerned, because this whole complex of ideas seemed linked to potentially quite dangerous political currents: manipulative and connected with behaviorist concepts of human nature.' (p. 80).

Barsky gives a blow-by-blow account of Chomsky's political development and activities starting from his childhood and ending up with a picture of 'Noam Chomsky, sixty-eight years old, Institute Professor, linguist, philosopher, grandfather, champion of ordinary people.' (p. 217). Chomsky's involvement in language and linguistics is touched on only tangentially - mostly based on secondary sources.

Considering that such a large part of Chomsky's public life has been circumscribed by his involvement in protest movements of one kind or another, one aspect struck me as highly significant. In the current century, one seminal contribution of India to socio-political behaviour has been the theory and practice of morally-tenable civil disobedience. There is no evidence whatever of any awareness of this either on the part of Chomsky or of the author of this political biography.

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**Rural and Renewable Energy: Perspectives from Developing Countries.** P. Venkataraman, ed. Tata Energy Research Institute, Darbari Seth Block, Habitat Place, Lodi Road, New Delhi 110 003. 1997. Price not known.

This volume is a collection of papers from several sources - some specifically written for this volume, and some drawn from

earlier publications. It has 24 contributions, of which 15 contributions are from India with 11 of them from Tata Energy Research Institute, the publishers, and 9 are distributed between Brazil, China, Senegal, Pakistan, France, UK, Denmark and USA. The Indian view is overly TERI view and it is not obvious that there are no other thinkers, contributions from whom would have enriched the reading. A large part of Latin America is un-represented and Africa implies Senegal in this volume. Thus more effort to obtain issues from other countries in the African continent, both success stories and unsolved problems would have benefited the volume. A substantive part of the book is a critique of the impact of governmental interventions into rural development and the way policies impact on the lives of large populations. Also there are insights into what might work and what will not. One example of this appears in Goldenberg's one and a half page article in which mass production of portable stoves reduced the cost of stoves from US 12\$ to 2\$ and this seems to have created a large private industry catering the large employment and also served the needs of a large population in Kenya.

Chandrasekhara Sinha, Venkataramana and Veena Joshi discuss rural energy planning with regard to effective intervention strategies. This article reprinted from an earlier 1994 publication presents several national programmes, the National Programme on Biogas Development (NPBD), National Programme on Improved Chulas (NPIC), Integrated Rural Energy Programme (IREP) and Urjagram and a critique on these. The main point made is that these programmes must be a part of total development rather than individual activities for them to have an impact of significant measure. While there can be no dispute about this point, one can also argue tackling the entire gamut of issues is complex and sorting out issue by issue might contribute to societal development in a reasonable measure. In a subsequent article, Chandrasekhara Sinha and Veena Joshi examine the biofuel demand estimation in rural domestic scene based on the earlier reports of various governmental committees. They bring out significant differences between various reports and attempt at rationalizing the results. They point out a direction of work, which might generate good database for about 3000 villages. In another paper, Venkataramana and Veena Joshi discuss

trends and issues in the use of biofuels in India and identify issues of data acquisition methods and assessment of accuracy of data. There does not appear clear focus in this paper as most points discussed are too general. The article by Archer on the application of geographic information system (GIS) for assessing bioresidue availability with details of results from Pakistan is an illuminating article in an area where enough work has not been completed in India. This paper outlines the methods used to obtain accurate estimates from satellite imagery, ground truth surveys and other collateral information. The principal message is that rapid assessment on large scale is indeed possible. Sorensen in another article argues for rural energy options, which are very unconventional – to rely on state-of-the-art technologies manned by highly educated sections settling in rural areas. While all assessments indicate to urbanization, the thesis in this paper that urbanites will move into villages and work towards better quality of life – appears very utopian. Kishore has made a critical assessment of renewable energy technologies for India – imports vs indigenous development. This article has many incisive observations; but has bloomers as well. The criticism about the need to modify the unqualified acceptance and support to solar photovoltaics is very valid. The comment about the need to import selective coatings technology for SPVs is ill informed since the National Aerospace Laboratories (and not Limited as indicated in the article) has developed them and the know-how has already been transferred to private industries. The table of comparison on the area required to generate a certain amount of power through the use of different technologies can be misleading if it is not combined with other aspects like cost and subsidiary benefits. For instance, it is not necessary to grow fuel wood trees or energy forest as it is called. Why not grow a mixed forest including horticultural plantations so that the annual productivity can be much higher and the magnitude of the residue is still reasonably high. The account of biomass gasification programme is incomplete and imbalanced in several places. The presentation on bio-methanation has some truths and half-truths. The fact that chemical engineering inputs have not been received for the development of biogas plants is correct. However, that one can generate power from biogas plants and put into grid

seems exaggerated since the magnitude of power that can be generated is small in most cases – typically up to about 20 kWe or so. It is only in distilleries where large bio-methanation plants exist, one can contemplate larger scale power generation about a few MWs, but the industry has sufficient absorbing capacity and no power need be pumped into the grid. Shukla in an interesting article uses Market Allocation model (called MARKAL) to examine the role of renewable energy technologies in India. The penetration will depend on the relative costing of the technologies, which is not indicated. Aspects of carbon tax and fuel cost scenarios are included in the forecast. The conclusion appears to be that subsidies may be unavoidable. With the fuel costs going up an energy tariff structure changing all over the country, it is not clear how many conclusions are indeed valid. There are a number of other articles, notably by Ajit Gupta of MNES, Naidu from IREDA, Pradeep Monga from UNDP (India), which describe the issues related to policies, financial incentives, institutional barriers which are indicative of the status about two years ago. With so many discussions of the possibilities of renewables in seminars and symposia the dynamism in introducing venues for renewables has increased several fold in the last two years.

The contents of the book encompass all the renewables and the distinction between rural energy and renewable energy is lost. For instance, the grid connected wind power has as much relevance as another large power station in feeding into grid which is perennially known to be not stable and has at best weak relevance to rural energy. The article on small hydro development by Arun Kumar of TERI is an essay on many issues on the periphery of rural energy. This is because one cannot expect the location of streams for harnessing hydropower to be close to villages.

On the whole, the book does give a perspective of renewable energy and views on matters some of which could be more wholesome. Followers of renewable energy will find parts of this book useful, parts they will disagree and with the latter position, much discussion will ensue.

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